The Comparison of Technical Efficiency and Productivity Growth in Transition Countries and the Soviet Union Countries

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Abstract

This study compares economic performance of the 15 transition economies for two periods: The Soviet Union Countries and transition countries. These periods include data of countries for 1970-1989 and 1991-2003. It is known that centrally planned economies are criticized for widespread economic inefficiency and low total factor productivity. Thus, in order to see how the efficiency levels and productivity growth of the former Soviet Union countries have changed during the transition or market-based period, we compare two periods using Data Envelopment Analysis.

The results of analysis indicate that, on average, technical efficiency has slightly increased, however, total factor productivity decreased due to technical regress over the transition period when compared to the era of Soviet Union for 15 countries.

Introduction

The Soviet Union grew rapidly through the mid of 1970s due to rapid and successful planned capital accumulation[1]. Therefore, a powerful rivalry occurred between the Soviet Union and the United States until 1980s. However, in the mid of 1980s, the political and economic structures of the Soviet Union and the Eastern European planned countries started to crumble (Case and Fair, 2004).

By the end of 1991, the Soviet Union collapsed and the fifteen Soviet Union countries declared their independences. The 12 of these countries formed the commonwealth of Independent States, CIS, in December 1991 except for Baltic countries (Estonia, Latvia and Lithuania). After collapse of the Soviet Union, these 15 countries have also decided to transform from planned economy to market-based economy. Then they are called the transition economies. It is argued that the underlying economic reason of the transition was the ever-worsening economic inefficiency in the pre-transition period due to economic production occurred overwhelmingly in the public sector and the use of resources was determined by political decisions made within the planning office. Therefore, it is expected that economic efficiency would increase after transition to the market economy. However, at the beginning of the transition the production efficiency; therefore, the per capita GDP decreased. Most transition economies recovered pre-transition GDP levels only after 2000 (Deliktas and Balcilar 2005).

For most analysts (see e.g. Lipton and Sachs (1990), Hinds (1990), establishing the market economy in transitional economies mainly depends on four inter-related policies on the micro-economic side: price liberalization, integration to the world economy, reducing barriers to entry by new firms and privatization. These policies also suggested by the International Monetary Fund and the World Bank (Deliktaş and Emsen, 2002). They are the main ingredients of a successful transition from socialist economy to a market based economy. The establishment of market supporting institutions, social safety to deal with unemployment and poverty, and external assistance have also a vital importance in transition process. The transition process to a market economy is not complete until these ingredients can be reached. It was hoped that these policies taken together would motivate a supply response at the industry level which would alter the structure of national production, the pattern of sales, both domestically and internationally, the quality and variety of output and enterprise productivity (Estrin, 1996).

However, transition process to market economy is not easy and may take a longer time. Advocates of shock therapy believe that the economies in transition should proceed immediately on all fronts. On the other hand, advocates of a gradualist approach suggest building up market institutions first, gradually decontrol prices, and privatize only the most efficient government enterprises first. Of course, these two approaches may have different effect on performances of economies. Deliktaş ve Balcilar (2005) indicated that the annual mean technical efficiency level of advanced reformers is higher than that of the slow reformers in 1991-2000. However, the advanced reformers had a larger total factor productivity decline than the slow reformers due to technical regress in the same period.

[1] The Soviet Union’s economy was growing much faster than that of the United states during the late 1950s (Case and Fair, 2004).

Generally, it is expected that transition to market economy would increase economic performance and then the transition economies have a higher of production frontiers in the transition period than in the pre- transition period. Because, the transition to market economy may cause production efficiency to increase due to private-owned enterprises, independent financial institutions. Accordingly, the transition economies can be thought of as operating either on or within best-practice frontier; and the distance from the frontier as reflecting inefficiency. Over time, a country can become less or more efficient and "catch-up" to the frontier or the frontier itself can shift, indicating technical progress. In addition, a country can move along the frontier by changing proportion of inputs used in production. Hence, output growth can be thought in terms of three different components: efficiency change, technical change, and input change. Economists often refer to the first two components collectively as "total factor productivity change" (Osiewalski et al. 1998)

In the literature, there are some studies about growth and performance measurement of nations. These studies use different approaches (Rao et al. 1998b). The first approach focuses on growth in real per capita income or real GDP per capita. This indicator can be considered as a proxy for the standard of living achieved in a country. The second approach is to examine the extent of convergence achieved by the poor countries and measure disparities in the global distribution of income. The third and most widely used recent approach is to consider productivity performance of economic decision units. This approach bases on a partial measure, such as output per person employed or per hour worked, and multi factor productivity measures based on the concept of total factor productivity and its components, such as technical efficiency change and technical change. Total factor productivity is considered as an important indicator of economic performance of nations. Technical efficiency change is also an indicator of the level of catch-up and convergence among the countries (Deliktaş and Balcılar 2005).

In this paper I employ the Malmqüist total factor productivity change index developed by Caves et al., 1982. In our study, following Fare et al., 1994, Malmqüist TFP change index is considered as a joint effect of the shift in the production frontier (technological progress) and a movement towards the frontier (efficiency change). The Malmqüist TFP change index is computed by the data envelopment analysis (DEA).The DEA used here is deterministic. There some advantageous of this approach: It does not require a specific underlying functional form. It enables a decomposition of TFP growth into changes in technical efficiency and changes in technology. The DEA has been widely used in various areas (Coelli and Rao, 1998).

The main objective of this paper is to examine how much progress has the Former Soviet Union (FSU) countries made in terms of technical efficiency and total factor productivity growth by considering two periods: pre-transition period (1970-1989) and transition period (1991-2005).

The remainder of the paper is organized as follows. The second section briefly outlines the major sources of data and describes all the variables used in the study. The third section defines the methodology used in the analysis. The fourth section presents empirical results and the fifth section concludes the paper.

Data

Measurement of total factor productivity usually requires either data on input and output prices or the measures of inputs and output. As known, it is difficult to collect data on the prices of inputs and output. However, Malmqüist indices require information about quantities or values of inputs and outputs not prices. The inputs and outputs of decision-making units are used to determine distance functions by the DEA. In this paper, the input and output data of the FSU countries for transition period were obtained from the World Development Indicators 2006 (WDI) published by the World Bank. On the other hand, data for the pre-transition period were obtained from the Center of Economic Analysis and Forecasting in Moscow. All data for the pre-transition period is annual for 1970-1990. For the pre-transition period output was measured by real net material product (in 1973 constant rubbles)[2] and capital input was measured by capital stock in 1973 constant rubbles and labor was measured by the number of employment. In transition period, output was measured by real GDP (constant 1995 US dollars) for each country. Inputs used in our model are labor and capital. Labor input was measured as the total labor force**.** The capital stock for each country was cumulatively calculated from gross fixed capital formation (constant 1995 US dollars) by taking 1989 as the base year for the transition countries.

Methodology

In this study the measure we use to analyze productivity performance of the FSU countries is the DEA based on Malmqüist TFP indices. These indices were introduced by Caves et al., 1982. Malmqüist indices allow for technical efficiency change and technological change indices by means of distance functions. The distance functions can be either in input-oriented form or output-oriented form. The output-oriented form is used in this study. Because it is more appropriate to investigate the achievable maximal output increase with respect to the allocation of inputs rather than to calculate the maximum proportional contraction of the input vector (Angeriz et.al. 2006).

As stated by Fare et al., 1994. By following Coelli et al., 1998, p.158 and Fare et al., 1994, we define a production technology at time t=1, …T, which represents the outputs, $y_t = (y_t^1, \ldots, y_t^M)$, which can be produced using the inputs $x_t = (x_t^1, \ldots, x_t^k)$, as:

$$R^t = \{(x_t, y_t) : x_t \text{ can produce } y_t\}. \qquad (1)$$

The equation (1) represents the feasible output set that can be produced by the given input vector. Following Shephard 1970, the output distance function relative to technology of R^t can be defined as:

$$D_0^t(x_t, y_t) = \min\{\varphi : (x_t, y_t / \varphi) \in R^t\}. \qquad (2)$$

[2] NMP = Net Material Product. The Soviet concept of Net Material Product omitted from GNP services not directly related to production, such as passenger transportation, housing, and output of government employees not producing material output.

The distance function is the inverse of Farrel's, 1957, measure of technical efficiency, which calculates how far an observation is from the frontier of technology. Distance $D_0^t(x_t, y_t) = 1$ if and only if (x_t, y_t) is on the frontier of the technology, $D_0^t(x_t, y_t) \leq 1$ if and only if $(x_t, y_t) \in R^t$ (Karadağ et al. 2005).

Similarly, the output-oriented distance function can be defined with respect to period t benchmark technology as

$$D_0^t(x_{t+1}, y_{t+1}) = \min\left\{\varphi : (x_{t+1}, y_{t+1} / \varphi) \in R^t\right\} \tag{3}$$

where φ corresponds to the minimum value required to deflate the period t output vector of the unit onto the production surface of a benchmark fixed in the same period.

Following Fare et al., 1994, Malmquist index of productivity change between period *t* and *t+1* is defined as

$$MTFP_0^{t,t+1}(x_t, y_t, x_{t+1}, y_{t+1}) = \left[\left(\frac{D_0^{t+1}(x_{t+1}, y_{t+1})}{D_0^t(x_t, y_t)}\right)\left(\frac{D_0^t(x_{t+1}, y_{t+1})}{D_0^{t+1}(x_t, y_t)}\right)\right]^{1/2}, \tag{4}$$

where $D_0^{t+1}(x_t, y_t)$ denotes the distance from the period *t* observation to the period *t+1* technology.

Efficiency and technical changes are the two components of TFP change (see Nishimizu and Page 1982; and Fare et al., 1994, for pioneering studies) as defined below:

$$MTFP_0^{t,t+1}(x_t, y_t, x_{t+1}, y_{t+1}) = \frac{D_0^{t+1}(x_{t+1}, y_{t+1})}{D_0^t(x_t, y_t)} \text{ x } \left[\left(\frac{D_0^t(x_{t+1}, y_{t+1})}{D_0^{t+1}(x_{t+1}, y_{t+1})}\right)\left(\frac{D_0^t(x_t, y_t)}{D_0^{t+1}(x_t, y_t)}\right)\right]^{1/2}, \tag{5}$$

The first term on the right-hand side of equation (5) represents the technical efficiency change (EC) and measures the convergence or catch-up performance of the country to the best-practice frontier by comparing the technical efficiency measure in period t+1 with respect to period t. The second squared bricked term on the right-hand side of equation (5) indicates technological change (TC) over time.

Hence Malmqüist total factor productivity change defined in equation (5) becomes

$$MTFP_0^{t,t+1} = EC \cdot TC. \tag{6}$$

When there is an increase in the level of productivity from period t to t+1 then the $MTFP_0^{t,t+1} > 1$, otherwise there is a decrease in the TFP if $MTFP_0^{t,t+1} < 1$ and no change if $MTFP_0^{t,t+1} = 1$ from period t to t+1. On the other hand, the index (EC) is bigger than one, it indicates that the country is catching up the best-practice frontier from period t+1 to period t. If the index is smaller than one, the country is falling behind of the best-practice frontier, and the index is one, the country has not improved its position with respect to the best-practice frontier between two periods. The TC index can also be explained in the same manner, but it provides a measure of the rate of change of the best-practice frontier between periods t+1 and t. If the index is bigger than one, it indicates technical progress and if it is smaller than it implies technical regress.

Malmqüist distance functions and therefore, total factor productivity indices mentioned above can be obtained by the DEA linear programming programs. The DEA method was developed by Charnes *et al*., 1978. Since then, there has been a large literature about the application of DEA methodology specifically in the area of calculations of TFP changes. Charnes et al., 1995, and Seiford, 1996, give the comprehensive review of this method. Also, panel data applications of DEA method are widely used in the literature (see for example, Milan and Aldaz, 2001; and Singh et al., 2000, Deliktaş 2002, Deliktaş and Balcilar, 2005, Karadag et.al, 2005, Deliktaş et al. 2005, Angeriz et al. 2006).

The output-oriented DEA model for a single output used in this study is closely related to Coelli et al., 1998. The model can be formalized as follows. Consider the situation for the N industries, each producing a single output by using K inputs. For the i-th industry x_{it} is a column vector of inputs, while y_{it} is a scalar representing the output. X denotes the $K \times NT$ matrix of inputs and Y denotes $1\times NT$ matrix of output. The CRS output-oriented DEA model is given by;

$$\max_{\phi,\lambda} \phi , \tag{7}$$

subject to

$$-\phi \ y_{it} + Y\lambda \geq \ 0 ,$$

$$x_{it} - X\lambda \geq 0 ,$$

$$\lambda \geq 0 ,$$

where $1\leq \phi < \infty$, λ is a $NT\times 1$ vector of weights. $1/\phi$ defines technical efficiency score, which varies between zero and one, with a value of one indicating any point on the frontier. The linear programming problem must be solved NT times in order to provide a value of ϕ for each industry in the sample.

Empirical results

Technical efficiency levels for transition economies

Table 1 presents estimates of annual means of efficiency levels for the transition economies over the 1991-2005 period. Efficiency index lies between zero and one. One indicates full efficiency and zero indicates full inefficiency for a country. The efficiency levels of countries are calculated by Equation (7) based on the DEA.

According to annual averages of efficiency levels for all countries, which are given in the second column of Table 1, Lithuania appears to be the most efficient countries, followed by Azerbaijan, Estonia, and Latvia. On the other hand, Tajikistan appears to be the least efficient countries, followed Ukraine and Belarus. Average efficiency level for the transition economies is 0.634 over the 1991-2005 period.

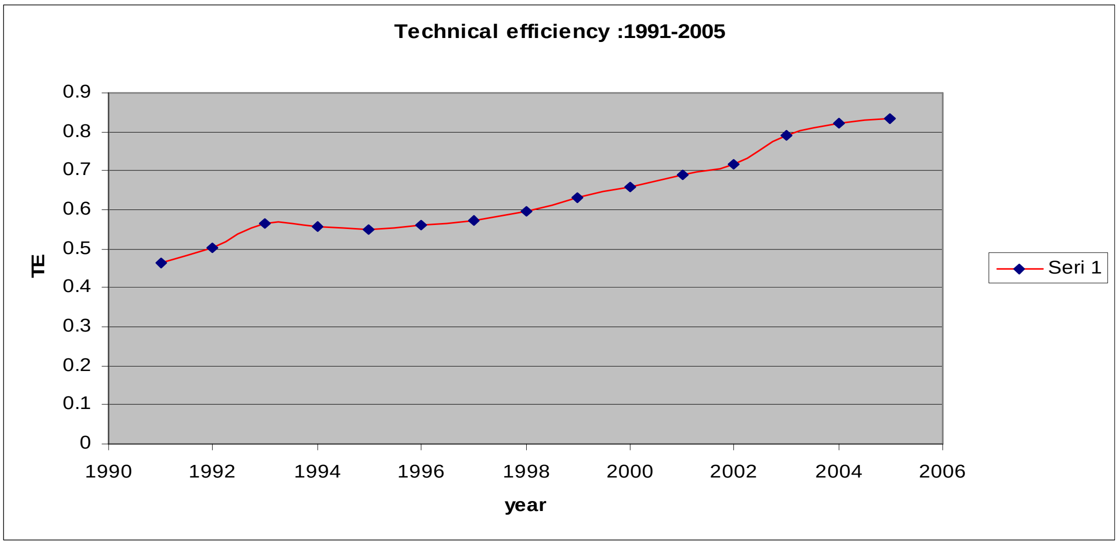
Table 1: Technical efficiency levels for transition countries (1991-2005)

Country	**Annual mean for each country** (1991-2005**)**	**Year**	**Annual mean of 15 countries**
Armenia	0.502	1991	0.463
Azerbaijan	0.979	1992	0.502
Belarus	0.473	1993	0.565
Estonia	0.978	1994	0.559
Georgia	0.532	1995	0.548
Kazakhstan	0.511	1996	0.561
Kyrgyzstan R.	0.567	1997	0.574
Latvia	0.944	1998	0.598
Lithuania	0.999	1999	0.633
Moldova	0.536	2000	0.657
Russian F.	0.614	2001	0.689
Tajikistan	0.422	2002	0.717
Turkmenistan	0.511	2003	0.790
Ukraine	0.430	2004	0.821
Uzbekistan	0.506	2005	0.832

The third column of Table 1 gives the annual means of technical efficiency scores of 15 countries for each year. This column indicates that the annual means of technical efficiency scores increased from 0.463 to 0.832 over the 1991-2005 period except for 1994 and 1995.

Figure 1 also shows annual means of technical efficiency scores of the transition countries over the 1991-2005 period.

Figure 1: Mean technical efficiency levels of transition economies



Technical efficiency change, technological change and total factor productivity change for transition economies

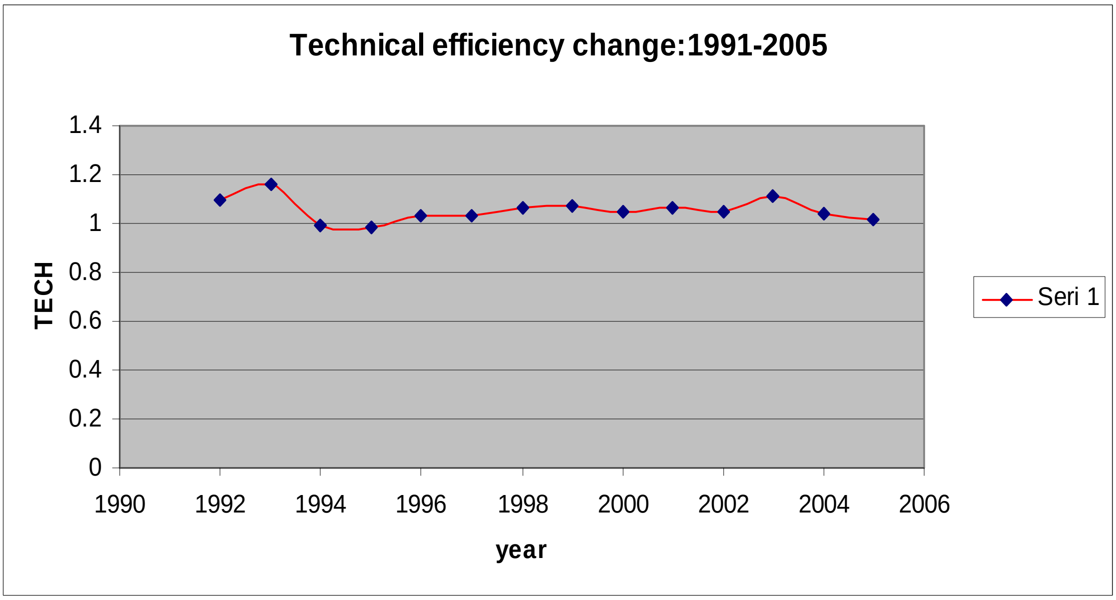
Table 2 presents the means for he technical efficiency change, technological change and total factor productivity change indices of the transition economies. Over the period of 1991-2005, the mean technical efficiency change is 1.054 and technological change is 0.854 and the TFP change is 0.902. As the table shows, the average rate of growth in the mean technical efficiency is 5.4 percent over the 1991-2005 period. The increasing efficiency over the entire sample period is an indicator of a country’s performance in adapting the global technology, and therefore represents the catch-up factor (Rao and Coelli 1998b). The rate of growth in efficiency also indicates a more efficient use of the existing technology over time. Table 3 also presents information on the year-to-year evaluation of the TFP change and changes its components. The negative efficiency change occurred in1994 and 1995.

Table 2: Annual means of technical efficiency change, technological change and total factor productivity change in Transition economies, 1991-2005

year	Mean technical efficiency change	Mean technological change	Mean total factor Productivity change
1992	1.097	0.604	0.663
1993	1.164	0.699	0.813
1994	0.991	0.823	0.816
1995	0.986	0.893	0.880
1996	1.033	0.888	0.917
1997	1.034	0.911	0.942
1998	1.065	0.883	0.940
1999	1.076	0.884	0.951
2000	1.050	0.932	0.979
2001	1.061	0.940	0.998
2002	1.049	0.921	0.966
2003	1.111	0.888	0.987
2004	1.043	0.949	0.989
2005	1.015	0.844	0.857
Mean	**1.054**	**0.856**	**0.902**

Note: For each year, the change given is that over the previous year (e.g. 1992 gives the change over 1991-1992).

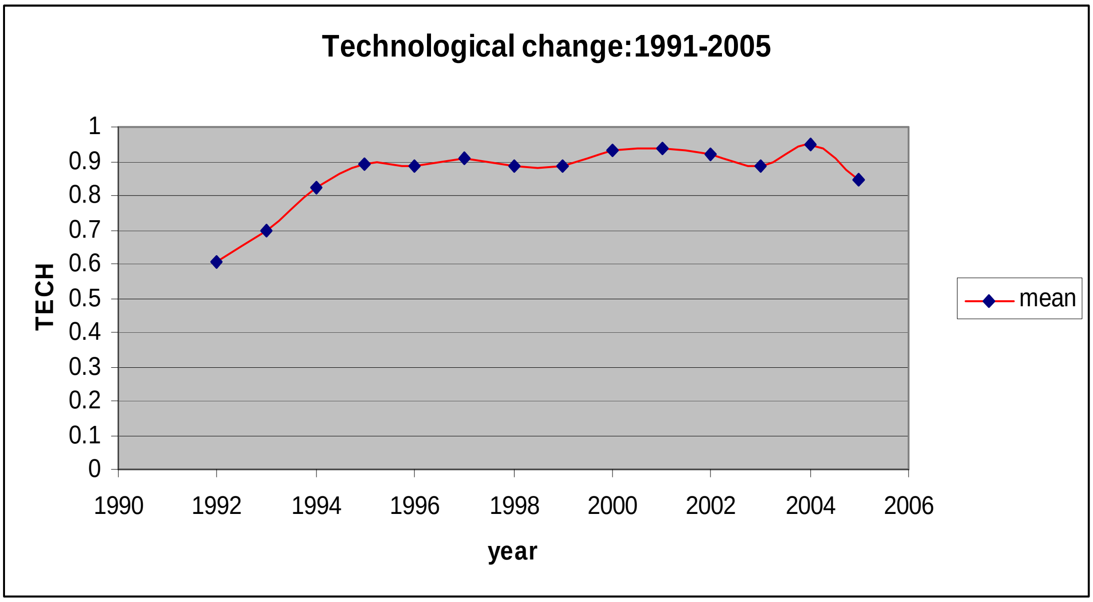
Figure 2: Mean technical efficiency change for transition economies



The third column in Table 3 shows that average technological change in transition economies is negative, with an average technical change about -14.4 percent, over the 1991-2005 period. That is, there is a technological regress over the whole period. The transition countries have suffered from substantial capital losses during the first half of

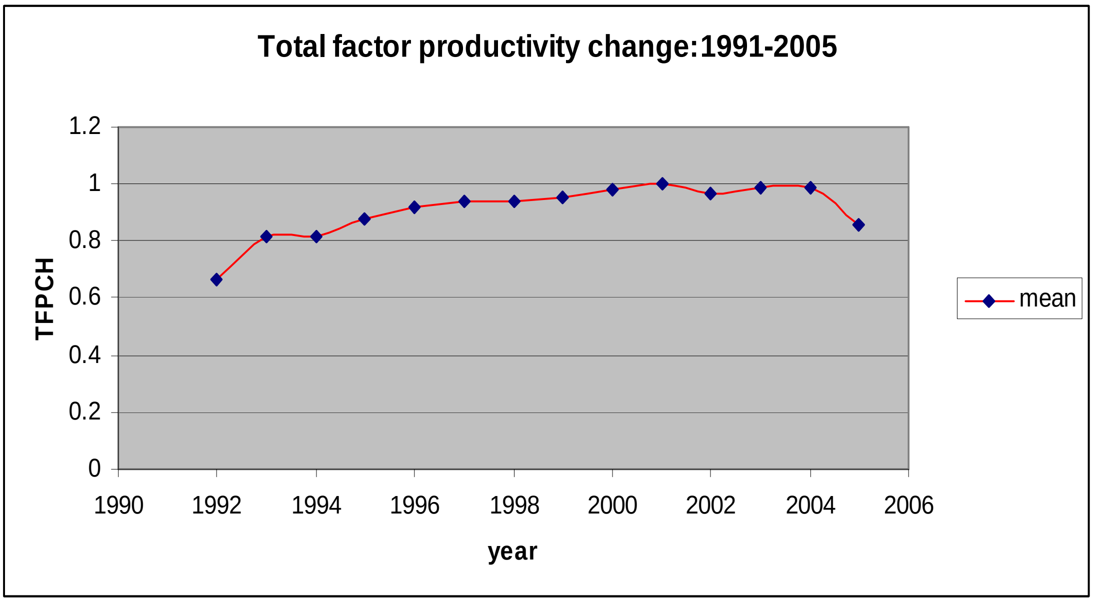
1990s. Therefore, a negative technical change is not unexpected for these countries (Deliktaş and Balcilar, 2005). Taskin and Zaim (1997) estimated a -1.38 percent technical change for low-income countries. Deliktaş and Balcilar (2005) estimated a -4.3 percent technological regress for 25 transition economies over the 1991-2000 period. Angeriz et al. (2006) calculated -2.7 percent technological regress for European Union regional manufacturing region over the 1986-2002 period.

Figure 3: Mean technological change for transition economies



The column four in Table 3 presents the TFP change indices for transition economies. The TFP growth is important because it determines the real standard of living that a country can achieve for its citizens. There is a simple link between productivity growth and the standard of living (Deliktaş and Balcilar 2005). The TFP change index can be decomposed into technical efficiency change and technological change as given equation (5). The decomposition of total factor productivity change makes it possible to understand whether the countries have improved their productivity levels simply through a more efficient use of existing technology or through technical progress. Furthermore, these two components make up for the overall productivity growth. The average annual TFP change index for the transition countries is 0.902 over the 1991-2005 period. The negative TFP growth rate is due to significant technical regress and slight increase in the efficiency. Overall, we observe that the average annual growth in technical efficiency is 5.4 percent, but the average annual technical change is -14.4 percent. The sum of these two changes is -9.8 percent. That is, the average annual TFP in the transition countries has declined by 9.8 percent over the 1991-2005 period due to a technical regress over the entire period.

Figure 4: Mean total factor productivity change for transition economies



Technical efficiency levels for the pre-transition economies

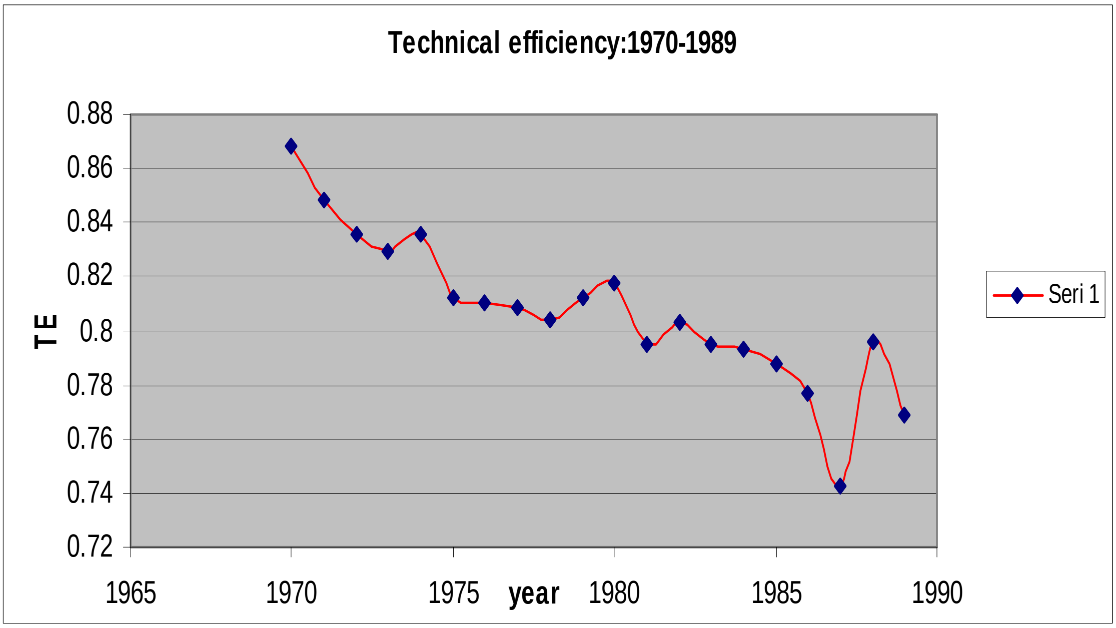
Table 3 presents estimates of annual means of efficiency levels for the pre- transition economies (or the FSU countries) over the 1970-1989 period. Over the entire period, average efficiency level for the FSU countries was calculated as 0.806. It is higher than that of transition period. According to annual averages of efficiency levels for all countries, Belarus and Latvia were the most efficient countries while Turkmenistan was the least efficient country in the same period. It is also seen that annual mean of technical efficiency score of 15 countries was the highest in 1970. The level of changes in technical efficiency is given in Table 4.

Table 3: Technical efficiency levels for the Soviet Union economies (1970-1989)

Country	Annual mean for each country (1970-1989)	Year	Annual mean of 15 countries
Armenia	0.933	1970	0.868
Azerbaijan	0.744	1971	0.848
Belarus	1.000	1972	0.836
Estonia	0.950	1973	0.829
Georgia	0.757	1974	0.836
Kazakhstan	0.607	1975	0.812
Kyrgyzstan R	0.747	1976	0.810
Latvia	1.000	1977	0.809
Lithuania	0.851	1978	0.804
Moldova	0.894	1979	0.812
Russian F.	0.862	1980	0.818
Tajikistan	0.730	1981	0.795
Turkmenistan	0.488	1982	0.803
Ukraine	0.826	1983	0.795
Uzbekistan	0.711	1984	0.793
		1985	0.788
		1986	0.777
		1987	0.743
		1988	0.796
		1989	0.769

Figure 5 shows annual means of technical efficiency scores of the pre-transition countries over the 1970-1989 period.

Figure 5: Mean technical efficiency levels in Soviet Union economies



Technical efficiency change, technological change and total factor productivity change for the Former Soviet economies

The second column of Table 4 gives the mean technical efficiency changes in the pre-transition period with respect to countries. Over the whole period mean technical efficiency change score is 0.992 indicating that the economies fell further behind the best-practice frontier. However, the positive efficiency change occurred for some years, such as 1974, 1979, 1980, and 1988.

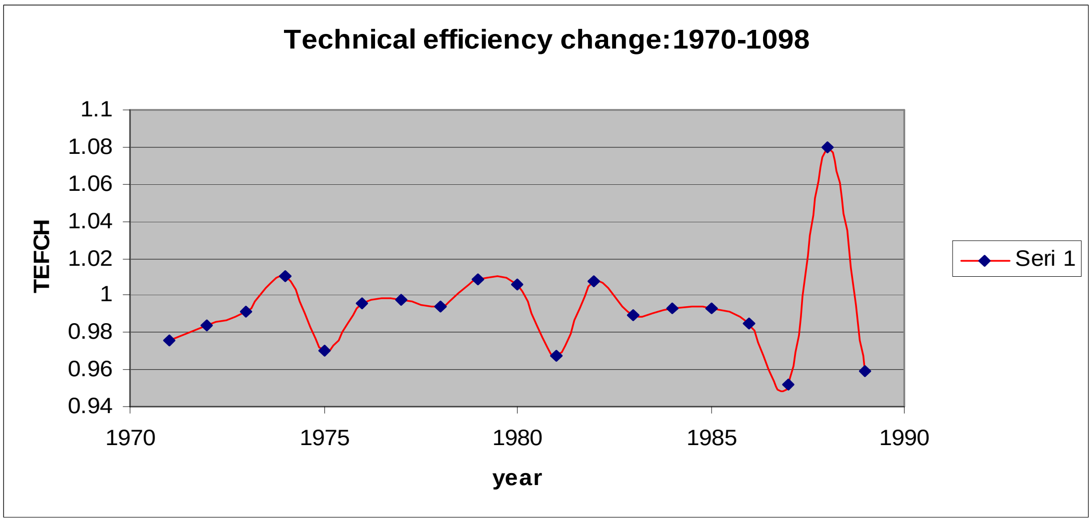
Table 4: Annual means of technical efficiency change, technological change and total factor productivity change in the Soviet Union economies, 1970-1989

Year	Mean technical efficiency change	Mean technological change	Mean total factor productivity change
1971	0.976	1.031	1.006
1972	0.984	0.999	0.983
1973	0.991	1.014	1.005
1974	1.010	0.995	1.005
1975	0.970	1,027	0.995
1976	0.996	1.008	1.004
1977	0.998	0.989	0.986
1978	0.994	1.006	1.000
1979	1.009	0.986	0.996
1980	1.006	0.990	0.996
1981	0.967	1.031	0.997
1982	1.008	0.990	0.997
1983	0.989	1.014	1.003
1984	0.993	0.997	0.990
1985	0.993	0.981	0.974
1986	0.985	1.001	0.986
1987	0.952	0.998	0.941
1988	1.080	0.997	1.077
1989	0.959	1.050	1.008
mean	**0.992**	**1.005**	**0.997**

Note: For each year, the change given is that over the previous year (e.g. 1971 gives the change over 1970-1971).

Figure 6 presents mean technical efficiency change of the FSU countries over the 1970-1989 period. In this period, technical efficiency change fluctuated and decreased on average.

Figure 6: Mean technical efficiency change for the Soviet Union economies



The third column of Table 4 presents mean technological change indices of the FSU economies in the study period. The average annual technological change was 1.005. That is, this period had a technical progress, on average. However, some years negative technological changes were recorded. The mean of technological change is presented by Figure 7.

Figure 7: Mean technical change for the Soviet Union economies

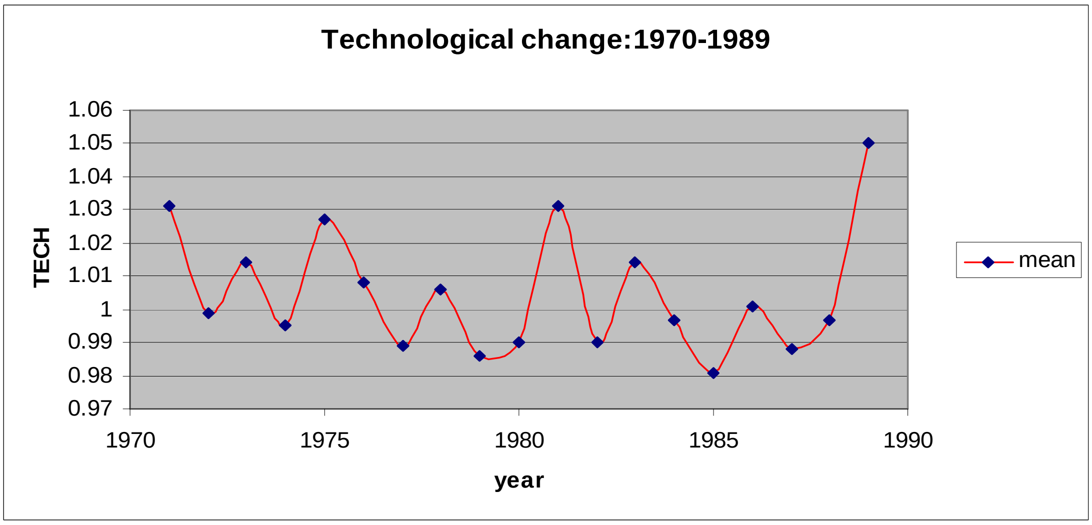
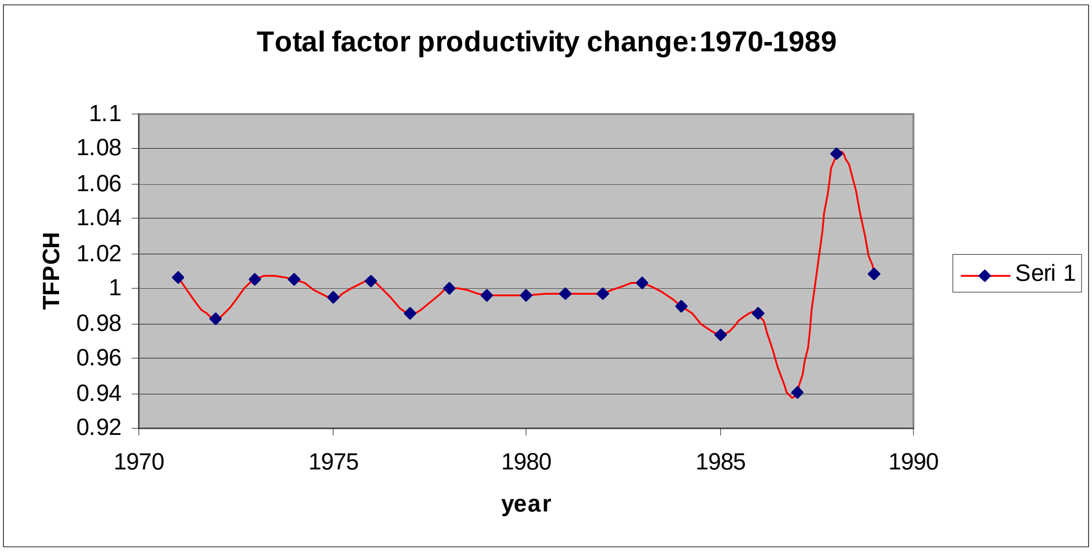


Table 4 also presents the mean of total factor productivity change over the 1970-1989 period. The mean of TFP change was 0.997, which can be decomposed into technical efficiency change of 0.992 and technological change of 1.005. The mean TFP change index indicates that the Soviet Union economies experienced a negative factor productivity growth due to the declining technical efficiency level over the entire sample period. In this period, the technological progress was offset by a declining technical efficiency, so that the TFP growth of -0.03 percent per annum was measured.

Figure 8 presents the TFP growth scores of the FSU economies over the period 1970-1989. It is seen that the TFP growth almost smoothly moved from 1970s until the mid of 1985s, but then it dropped in 1987 and sharply increased due to technical efficiency increase in 1988 and technological progress in 1989.

Figure 8: Mean total factor productivity growth for the Soviet Union economies



Conclusion

I calculated Malmqüist total factor productivity indices for the 15 transition economies over the 1991-2005 period and the Soviet Union economies (after 1991 they are called transition economies) over the 1970-1989 period using the DEA methods.

According to findings of the study, the transition to the market economy reduced inefficiency in the formerly planned economies. These economies have an increasing efficiency level over the transition period, on average. On the other hand these countries have suffered from technical regress and the overall result has been an average total factor productivity decline.

In the Soviet Union, while the countries had a technological progress, on average, they had a declining efficiency level in the 1970-1989 period. In both periods, the TFP growth is negative. The negative TFP growth in transition period can be explained by technical regress while the negative TFP growth in the pre-transition period can be explained by a declining technical efficiency level.

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